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TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 221

THE EFFECT OF BOW STIFFENERS IN NONRIGID AIRSHIPS.

By Edward P. Warner.

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It is now well known that all nonrigids constructed at the present time have bow stiffeners consisting of battens curved to the form of the envelope and designed to hold the nose of the ship in its true form despite the very large pressure which exists at the extreme forward point. The effect of the stiffeners is to reduce considerably the apparent pressure which has to be maintained inside the envelope in order to prevent the nose from caving in.

If no stiffening battens were used it is obvious that the in-inside pressure would have to be greater than the dynamic pressure against the outside of the envelope at any point. Since the pressure at the extreme nose is always equal to $\frac{1}{2} \rho V^2$, the pressure on the dynamic side of a pitot tube at the same speed, the apparent gas pressure at a speed of 60 M.P.H. through quiet air, would have to be 9.09 lbs per sq.ft., or 1.75 ins. of water at the center line of the ship. The maintenance of this pressure at the nose when diving at an angle of thirty degrees would involve a pressure of 3.1 ins. of water in a 200,000 cu.ft. ship 200 ft. long. This pressure, however, would suffice only barely to hold the envelope in shape in still air. Some factor of safety must be allowed to take care of gusts, accelerations of the ship, changes of internal pressure due to surging of the gas, and other departures from standard conditions, and it is wise to choose the internal pressure to give maintenance of form at a speed 15 M.P.H. higher than the speed of flight of the ship. It is especially important that a good margin of safety be allowed above the minimum possible pressure if stiffeners are used, as the caving in of the nose under an excess of dynamic pressure is then likely to cause the battens to punch through and tear the envelope, whereas caving in of the nose of a ship fitted only with a small round nosecap is not likely to cause any damage, and the original form will be restored as soon as the pressure is raised to its proper value. Taking 75 M.P.H. in place of 60 in the case just cited, the figures for horizontal and inclined flight become 2.73 ins. of water and 4.08 ins. The larger of these pressures, while it would not actually involve danger of bursting the fabric in a new ship, would allow but little margin for deterioration of the envelope before a really dangerous condition would be reached, and would help to hasten that very deterioration, as the life of a rubberized fabric is much shortened by an increase in the stress continuously applied. Furthermore, the maintenance of such an internal pressure would be impossible with the usual arrangement of scoops lowered into the slipstream of the propellers and would require the use of blowers of some sort. Since the velocity in the slipstream is only about 30 per cent higher than the velocity of flight, and since the pressure at the mouths of the scoops through which the ballonets are filled is always $\frac{1}{2} \rho V_S^2$ (V_S being the relative airspeed in the slipstream), the pressure in ballonets filled by scoops cannot exceed $.85\,\rho\,V^2$, even if frictional losses in the fabric ducts leading to the ballonets be neglected entirely. This, at 60 M.P.H., is only 2.96 ins of water, a pressure far inferior to that required in inclined flight if bow stiffeners are lacking. From this it is evident that the use of the battens is almost a sine qua non of success if the ballonets are to be filled from scoops, even if the speed of flight is so slow that the stresses in the fabric are negligible.

If it be admitted that stiffeners of some sort must be used, there remains a question as to how long they shall be and just how much reduction of internal pressure they make possible. The answer to these questions can only be determined from an analysis of the pressure distribution over the envelope, but they rest fundamentally on the necessity of keeping the envelope fabric in tension at all points. Considering that portion of the nose which is supported by the stiffeners as a rigid body, the maintenance of tension in the envelope requires that the algebraic sum of all the air and calculated in the same way, but the total can only be determined by graphical methods or by the direct summation of the forces on all the annular elements, as the external pressure due to motion through the air varies from point to point along the surface of the envelope in a manner which can be found only by experiment.

The necessary calculations have been carried through for two envelopes, for which pressure distribution data are available,* and the results are given in Fig. 1. The curves have been carried back from the nose only for a distance of .75 of the maximum envelope diameter, and the lengths are given, in both cases, in terms of the maximum diameter, although the fineness ratio is quite different for the two forms chosen. The U.721 represents modern practice most nearly, and is particularly interesting as having given a lower resistance in proportion to volume and to cross-section area than any other form yet developed, the resistance being only 1/43 of that of a flat plate of the same projected area. The first pair of curves simply show the form of the forward part of the envelope, while the second pair, marked "intensity of pressure," is a direct plotting of the results of the pressure distribution tests, the pressure being given in every case as a fraction of the dynamic head of a pitot tube at the same speed. The third set, "average longitudinal component of pressure," have as their ordinates the average longitudinal component of external pressure on

* Determination of the Pressure Distribution over the Surface of a Dirigible of Parseval Form, by A. Fage and W. J. Stern, p.68, Tech. Report of British Advisory Committee for Aeronautics, 1913-1914. The Distribution of Pressure over the Surface of Airship Model U.721, by R. Jones and D. H. Williams; R. & M. 600, British Advisory Committee for Aeronautics, London, 1919.

the portion of the envelope forward of the point represented by

[illegible]

the envelope, but to the cross-sectional area, and the ordinates of this curve therefore give directly the internal gas pressure that would have to be maintained in order to prevent caving in of the nose with battens running back to any desired distance along the surface. In case the battens are of such a length that their projection on the axis extends back 1/10 of the maximum diameter from the nose, for example, the ratio of the internal pressure required to the dynamic pressure of a pitot tube is .62 for the U.721 and .43 for the Parseval. In the case of the Parseval envelope, with its rather pointed nose, the pressure drops off so rapidly that even a cap covering the nose and extending only 1 foot along the axis on a 200,000 cu.ft. ship suffices to reduce the necessary gas pressure by 16 per cent.

Returning to the original problem of choosing stiffeners such that the required pressure can be maintained by the use of scoops in the slipstream, the dynamic pressure in the slipstream may be long at 60 M.P.H. Deducting the pressure due to inclination from the maximum provided by the scoops, there remains .94 times the pitot head, and this must be equated to the pressure required to hold the nose in form under the worst conditions. Dividing through by the factor 1.56, this is found to be equal to .60 times the pitot head under normal conditions, and Fig. 1 shows that this is equal to the main pressure over the stiffened area of the nose when the nose stiffeners run back along the axis .105 times the diameter in the U.721 and .055 times the maximum diameter in the Parseval. The figure given for the U.721 approximates to the length of stiffener used in most nonrigids at the present time.

In Fig. 2 the pressures required with bow stiffeners of various lengths have been plotted against radius at the ends of the battens instead of against distance from the nose. This gives a better idea than does the first method of the actual length of batten which must be employed, but it will be noted that the curves for the two forms are closer together in Fig. 1 than in Fig. 2, and this seems to indicate that the curve of pressure against axial length would be the better one to employ if the data here given were to be applied to a new form for which no pressure distribution data were available.

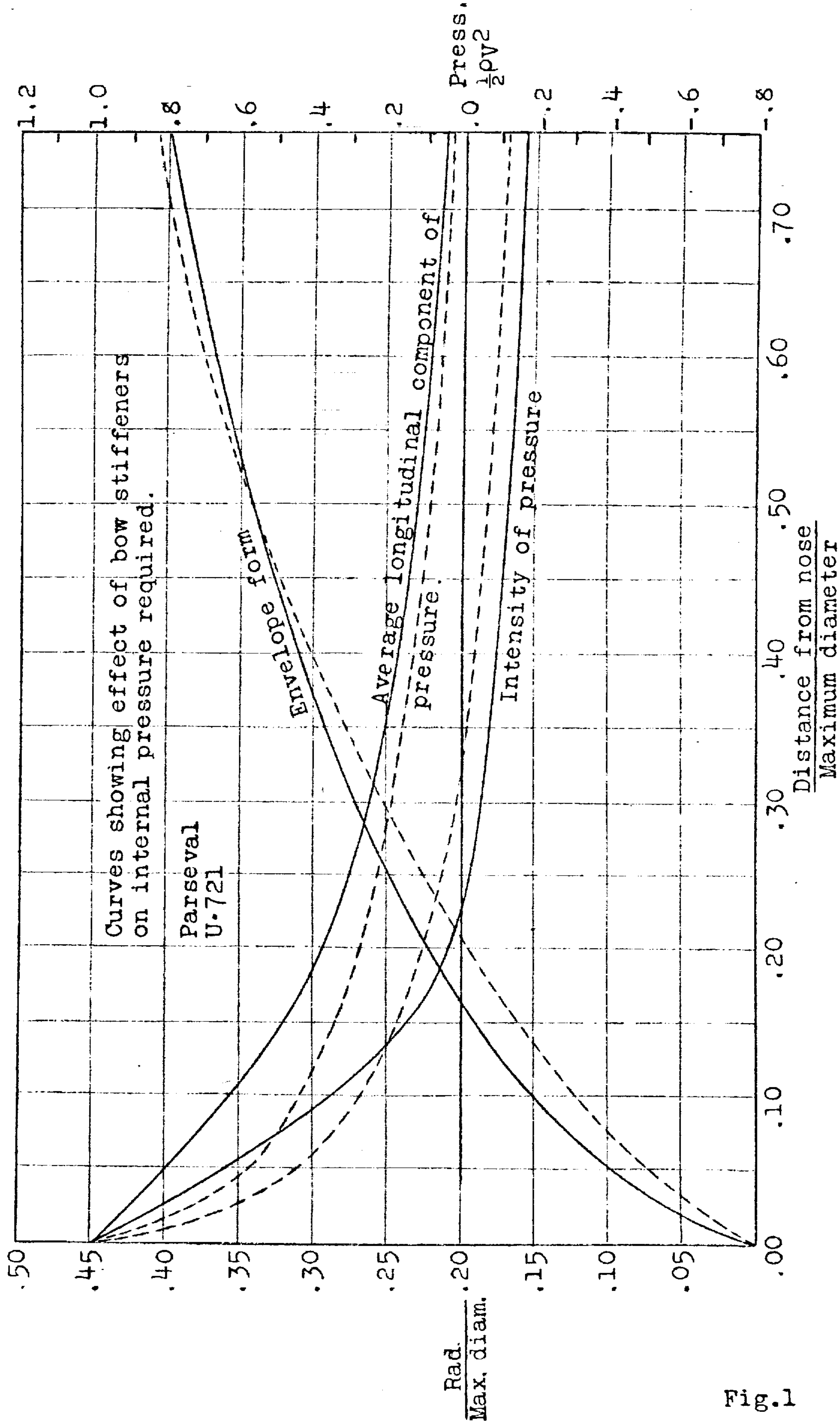
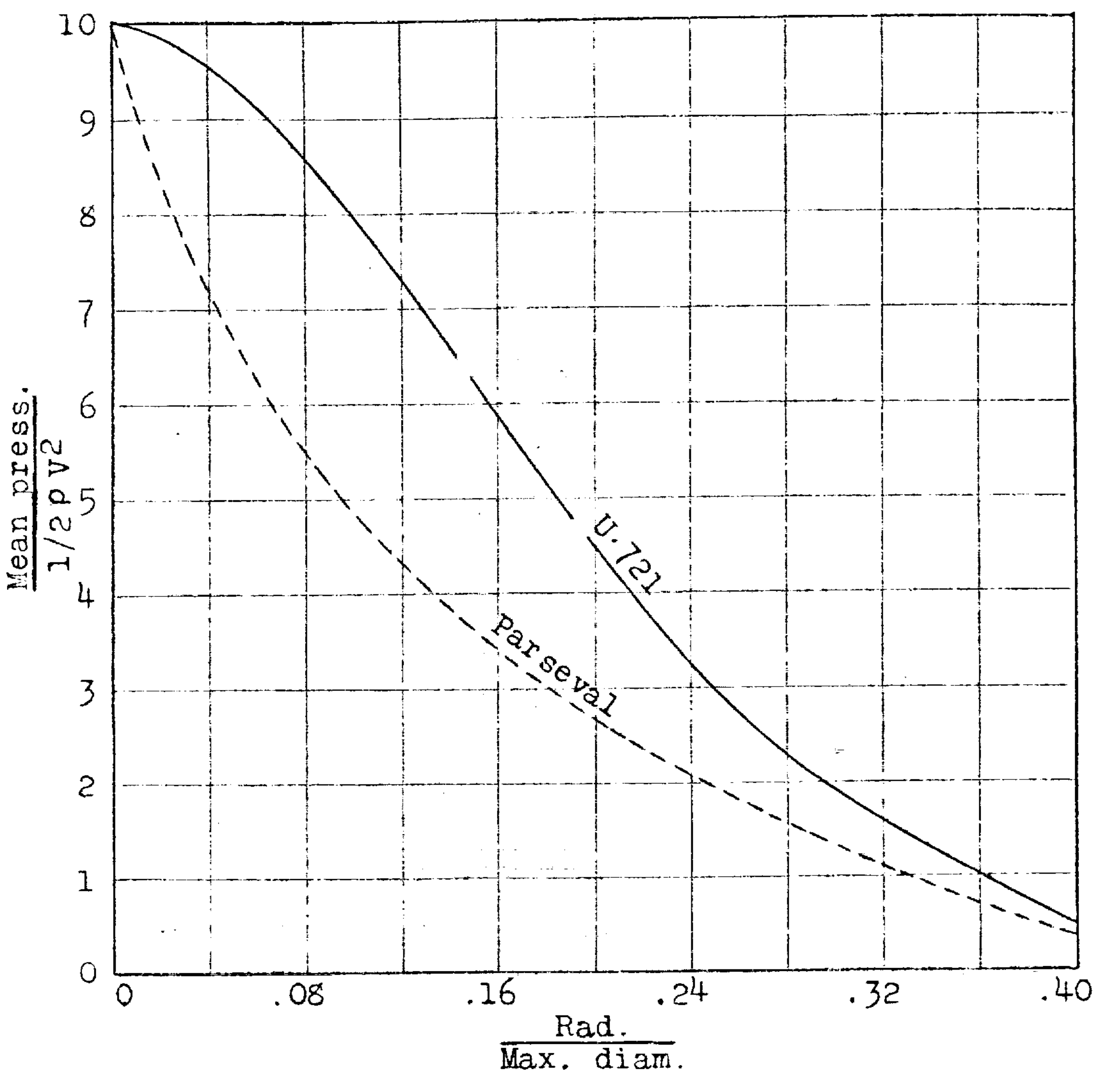

Curves showing effect of bow stiffeners on internal pressure required.
Parseval U-721
Envelope form
Average longitudinal component of pressure
Intensity of pressure
Distance from nose / Maximum diameter
Rad. / Max. diam.
Press. / $\frac{1}{2}\rho V^2$
.00 .05 .10 .15 .20 .25 .30 .35 .40 .45 .50
.10 .20 .30 .40 .50 .60 .70
1.2 1.0 .8 .6 .4 .2 0 -.2 -.4 -.6 -.8

Fig.1

Fig. 2



10
9
8
7
6
5
4
3
2
1
0
Mean press. / 1/2 ρ V²
0
.08
.16
.24
.32
.40
Rad. / Max. diam.
U.721
Parseval

Fig. 2